V. Environmental Impact Analysis

This section provides a description of the potential environmental impacts associated with operating the proposed reactors with mixed oxide (MOX) fuel. It replaces Section 4.28 in the Surplus Plutonium Disposition Draft Environmental Impact Statement *(SPD Draft EIS) and will be included in the SPD Final EIS under the same section number.*

The impacts associated with using mixed oxide (MOX) fuel during normal operations of the proposed reactors are not expected to be much different from those associated with the continued use of low-enriched uranium (LEU) fuel in these reactors. The radiation dose from normal operations to the surrounding population and workers at the reactors is not expected to change. Similarly, the amount of radioactive and hazardous waste generated during normal operation is expected to be the same regardless of fuel type. No changes are expected in the air or water quality surrounding the sites. If MOX fuel is used in these reactors, it is expected that about 5 percent more spent fuel would be generated by the reactors than if they continued to use LEU fuel. This increase in fuel is needed mainly during the transition from LEU fuel to a partial MOX core to maintain peaking in the reactors below design and regulatory limits and to compensate for greater end-of-cycle reactivity. Some additional assemblies are also expected to be needed by the North Anna reactors during equilibrium cycles. No other resource areas are expected to be impacted by the use of MOX fuel at any of these reactor sites. There are differences in the expected risk of reactor accidents from the use of MOX fuel. Some accidents would be expected to result in lower consequences to the surrounding population and, thus, lower risks, while others would be expected to result in higher consequences and higher risks. The largest estimated increase in risk to the surrounding population due to the use of MOX fuel is an estimated 15 percent increase in the risk of latent cancer fatalities (LCFs) associated with an interfacing systems loss-of-coolant accident (ISLOCA) at North Anna. The probability or frequency of this accident occurring at North Anna is estimated to be 2.4×10^{-7} *or 1 chance in 4.2 million per year of reactor operation.*

4.28 IMPACTS OF IRRADIATING MOX FUEL AT REACTOR SITES

The environmental impacts described in the following sections are based on using a partial MOX core (i.e., up to 40 percent MOX fuel) instead of an LEU core in existing, commercial light water reactors. As discussed in Section IV, the proposed sites are the Catawba Nuclear Station near York, South Carolina; the McGuire Nuclear Station near Huntersville, North Carolina; and the North Anna Power Station near Mineral, Virginia. Each of the proposed sites has two operating reactors that would be used to irradiate MOX fuel assemblies. All of these sites have been operating safely for a number of years. Table 4.28–1 indicates operating statistics for each of the proposed reactors.

Table 4.28–1. Reactor Operating Information

Reactor	Operator	Capacity (net MWe)	Date of First Operation (mo/yr)
Catawba 1	Duke Power	1,129	1/85
Catawba 2	Duke Power	1,129	5/86
McGuire 1	Duke Power	1,129	7/81
McGuire 2	Duke Power	1,129	5/83
North Anna 1	Virginia Power	900	4/78
North Anna 2	Virginia Power	887	8/80

Source: DOE 1996a.

Since 1978, the U.S. Nuclear Regulatory Commission (NRC) has conducted a systematic assessment of licensee performance (SALP) of each nuclear power plant in the United States. During a SALP, board members review inspection results; enforcement actions that may have been taken against a licensee; and results of the latest plant performance reviews, performance indicators, licensee self-assessments, third-party assessments, and indepth discussions with licensees. Regional managers used the SALP findings to identify those areas at a plant that required increased inspection. (In September 1998, NRC suspended the SALP program for an interim period while NRC reviews its nuclear power plant assessment process [NRC 1998].) Table 4.28–2 shows the results of the most recent SALP undertaken by NRC at each of the proposed reactor sites.

Table 4.28–2. Results of Systematic Assessment of Licensee Performance

	Catawba	McGuire	North Anna
Date of latest SALP	6/97	4/97	2/97
Operations	Superior	Superior	Superior
Maintenance	Good	Good	Superior
Engineering	Superior	Good	Good
Plant support	Superior	Superior	Superior

Source: NRC 1997a, 1997b, 1997c.

In accordance with the alternatives presented under the hybrid approach (i.e., Alternatives 2 through 10 in the SPD Draft EIS), all of these reactors would use MOX fuel to partially fuel their reactor cores. Up to 33 t (36 tons) of surplus plutonium could be used in MOX fuel at these reactors from 2007–2022. In March 1999, DOE awarded a contract to Duke Engineering & Services; COGEMA, Inc.; and Stone & Webster (known as DCS) to provide MOX fuel fabrication and reactor irradiation services contingent on the selection (in the SPD EIS Record of Decision) of the hybrid approach described in Chapter 2 of the SPD Draft EIS.

The analyses prepared for this section are based on information provided by DCS. Data was also developed independently to support these analyses. This included projecting the population around the proposed reactor sites to 2015[1] and compiling information related to the topography surrounding the proposed reactor sites for evaluating air dispersal patterns. Information to support accident analysis was also provided by Oak Ridge National Laboratory (ORNL). Based on information provided by DCS, ORNL developed expected ratios of radionuclide activities in MOX fuel versus that in LEU fuel as it would be used in the reactors. Standard models for estimating radiation doses from normal operations and accident scenarios, and estimating air pollutant concentrations at the proposed reactor sites were run using this new information. Human health risk and accident analyses were performed for a maximum use of a 40 percent MOX core, which is a conservative estimate of the amount of MOX fuel that would be used in each of the reactors.

Under the MOX approach, both MOX and LEU fuel assemblies would be loaded into the reactor. The MOX assemblies would remain in the core for two 18-month cycles and the LEU assemblies for either two or three 18-month cycles, in accordance with the plant's current operating schedule. When the MOX fuel completes a normal cycle, it would be withdrawn from the reactor in accordance with the plant's standard refueling procedures and placed in the plant's spent fuel pool for cooling alongside other spent fuel. No changes are expected in the plant's spent fuel storage plans to accommodate the spent MOX fuel. Eventually the spent fuel would be shipped to a potential geologic repository for permanent disposal.

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[1] Population projections for the area encompassed in a 80-km (50-mi) radius around the proposed reactor sites were projected to 2015 to approximate the midpoint of the irradiation services program. By 2015, the MOX program would be firmly established at all of the proposed reactor sites and would be expected to remain stable through the end of the program. Using 1990 census data as the base year and state-provided population increase factors for all counties included in this analysis, the population around the sites was projected for 2015. Baseline projections were needed for two of the reactor sites because the population information provided in the proposal was based on 1970 census data. Recent (i.e., 1990) census data were provided for the other proposed site and projected by the offeror to the years 2010 and 2020. From these data points, 2015 projections were interpolated.

4.28.1 Construction Impacts

The proposed reactor sites have indicated that little or no new construction would be needed to support the irradiation of MOX fuel at the sites. Any new construction would be inconsequential. As a result, land use; visual, cultural, and paleontological resources; geology and soils; and site infrastructure would not be affected by any new construction or other activities related to MOX fuel use. Nor would there be any effect on air quality and noise, ecological and water resources, or socioeconomics.

4.28.2 Operational Impacts

4.28.2.1 Air Quality and Noise

Continued operation of the proposed reactor sites would result in a small amount of nonradiological air pollutants being released to the atmosphere mainly due to the requirement to periodically test diesel generators. As shown in Section IV, all of the proposed reactors are operated within Federal, State, and local air quality regulations or guidelines. The estimated air pollutants resulting from operation of the proposed reactors would not be expected to increase due to the use of MOX fuel in these reactors. (See Tables 3.7–1, 3.7–6, and 3.7–11 in Section IV for projected concentrations at the proposed reactor sites.)

There would also not be any increase in the noise levels expected from the operation of these reactors due to the use of MOX fuel.

4.28.2.2 Waste Management

The proposed reactors would be expected to continue to produce low-level waste (LLW), mixed LLW, hazardous waste, and nonhazardous waste as part of their normal operations. The volume of waste generated is not expected to increase as a result of the reactors using MOX fuel. This is consistent with information presented in the *Storage and Disposition PEIS* that stated the use of MOX fuel is not expected to increase the amount or change the content of the waste being generated (DOE 1996b:4-734). (The amount of spent fuel generated would increase somewhat, as discussed in Section 4.28.2.8.)

As shown in Section IV, the estimated LLW generation for each of the proposed reactors is less than the amount estimated in the *Storage and Disposition PEIS* (DOE 1996b:4-734). (See Tables 3.7–2, 3.7–7, and 3.7–12 in Section IV.) None of these waste estimates are expected to impact the proposed reactor sites in terms of their ability to handle these wastes. The wastes would continue to be handled in the same manner as they are today with no change required due to the use of MOX fuel at the reactors.

4.28.2.3 Socioeconomics

The proposed reactor sites would not need to employ any additional workers to support the use of MOX fuel in the reactors. This is consistent with information presented in the *Storage and Disposition PEIS* which concluded that the use of MOX fuel could result in small increases in the worker population at the reactor sites (between 40 and 105), but that any increase would be filled from the area's existing workforce (DOE 1996b:4-727).

4.28.2.4 Human Health Risk From Normal Operation

There should be no change in the radiation dose to the general public from normal operation of the reactors with a partial MOX fuel core versus a full LEU fuel core. This is consistent with findings in the *Storage and Disposition PEIS* that showed a very small range in the expected difference: -1.1×10^{-2} to 2×10^{-2} person-rem

(DOE 1996b:4-729). Therefore, the doses would be approximately the same for either core. The annual estimated radiological releases from normal operation of the proposed reactors to the environment are shown in Table 4.28–3.

Table 4.28–3. Expected Radiological Releases From Continued Operation of the Proposed Reactors (Ci)

Reactor	Atmospheric Releases	Liquid Release	Total Estimated Release
Catawba	349.6	591.4	941.0
McGuire	165.2	626.1	791.3
North Anna	132.5	1,036.0	1,168.5

Table 4.28–4 shows the projected radiological doses that would be received by the maximally exposed offsite individual (MEI) and the general population based on the releases shown in Table 4.28–3. As shown in Table 4.28–4, the average individual living within 80 km (50 mi) of one of the proposed reactor sites could expect to receive an annual dose of between 2.5×10^{-3} to 9.9×10^{-3} mrem/yr from normal operation of these reactors regardless of whether the reactors were using MOX fuel or LEU fuel. This is a small dose compared with the average annual dose an individual would receive from natural background radiation near these sites (about 325 mrem).

Table 4.28–4. Estimated Dose to the Public From Continued Operation of the Proposed Reactors in the Year 2015 (Partial MOX or LEU Core)

Impact	Catawba[a]	McGuire[b]	North Anna[c]	S&D PEIS
Population within 80 km for year 2015				
Dose (person-rem)	5.7	10.7	20.3	2.0
Percent of natural background	7.7×10^{-4}	1.3×10^{-3}	3.0×10^{-3}	2.6×10^{-4}
Latent fatal cancers	2.9×10^{-3}	5.4×10^{-3}	1.0×10^{-2}	1.0×10^{-3}
Maximally exposed individual (mrem/yr)				
Annual dose (mrem)	0.73	0.31	0.37	0.17
Percent of natural background	0.22	0.095	0.11	0.052
Latent fatal cancer risk	3.7×10^{-7}	1.6×10^{-7}	1.9×10^{-7}	8.5×10^{-8}
Average exposed individual within 80 km				
Annual dose (mrem)	2.5×10^{-3}	4.2×10^{-3}	9.9×10^{-3}	7.8×10^{-4}
Latent fatal cancer risk	1.3×10^{-9}	2.1×10^{-9}	4.9×10^{-9}	3.9×10^{-10}

[a] The population for the year 2015 is estimated to be 2,265,000.
[b] The population for the year 2015 is estimated to be 2,575,000.
[c] The population for the year 2015 is estimated to be 2,042,000.
Key: LEU, low-enriched uranium; S&D PEIS, *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement.*

The average radiation worker at the proposed reactor sites could expect to receive an annual dose of between 46 and 123 mrem/yr from normal operations with a partial MOX core. (See Tables 3.7–5, 3.7–10, and 3.7–15 in Section IV.) As discussed in Section IV and Section VI (Appendix P), this is the same amount of radiation dose that would be received if the reactors continued to use only LEU fuel. This is because the MOX fuel would be shipped in safe, secure trailers (SSTs) and moved remotely or in shielded vehicles to the reactor's fuel staging area and finally into and out of the reactor core. The projection that the use of MOX fuel would not change the estimated worker dose is consistent with data presented in the *Storage and Disposition PEIS*, which showed an incremental increase in worker dose of less than 0.1 percent due to the use of MOX fuel (DOE 1996b:4-730).

4.28.2.5 Reactor Accident Analysis

The reactor accident analysis includes an assessment of postulated design basis and beyond-design-basis accidents at each reactor site. The accidents presented were selected because of their potential to release substantial amounts of radioactive material to the environment. A detailed discussion of the accident analysis methodology is provided in Section VI (Appendix K).

There are differences in the expected risk of reactor accidents from the use of MOX fuel. Risk is determined by multiplying two factors. The first factor is the probability or frequency of the accident occurring. In the case of the reactor accidents evaluated in this *Supplement*, no change has been made in the estimated frequency of the accident based on the presence of MOX fuel. The frequencies used in the analysis are the same as those used in each reactor's probabilistic risk assessment (PRA), which was prepared for NRC for the reactor's current LEU core. Although it has been suggested that the frequency of these accidents would be higher with MOX fuel present, no empirical data is available to support this. Further, the National Academy of Sciences has stated that "We believe, further, that under these circumstances no important overall adverse impact of MOX use on the accident probabilities of the LWRs involved will occur; if there are adequate reactivity and thermal margins in the fuel, as licensing review should ensure, the main remaining determinants of accident probabilities will involve factors not related to fuel composition and hence unaffected by the use of MOX rather than LEU fuel" (NAS 1995). The second factor in the risk equation is an estimate of what the consequences would be should the accident occur. Depending on the accident being analyzed, the presence of MOX fuel would decrease or increase the consequences of the accident because it would result in a different amount of radiation being released during the accident due to different isotopics and amounts of radioactive isotopes and noble gases being generated.

The change in consequences to the surrounding population due to the use of MOX fuel is estimated to range from 9.5×10^{-4} fewer to 5.5×10^{-2} additional LCFs for design basis accidents evaluated in this *Supplement*, to 7.5 fewer to 1,600 additional LCFs for beyond-design-basis accidents (14,800 versus 13,200 LCFs in the worst accident). Also, some of the beyond-design-basis accidents could result in prompt fatalities should they occur. The estimated increase in prompt fatalities due to MOX fuel being used during one of these accidents would range from no change to 28 additional fatalities (843 versus 815 prompt fatalities in the worst accident). As a result of these changes in projected consequences, there would be a change in the risk to the public associated with these accidents. The change in risk (in terms of an LCF or prompt fatality) to the surrounding population within 80 km (50 mi) of the proposed reactors is projected to range from a decrease of 6 percent to an increase of 3 percent in the risk of additional LCFs from design basis accidents, and from a decrease of 4 percent to an increase of 15 percent in the risk of additional prompt fatalities and LCFs from beyond-design-basis accidents.

The risk to the MEI would also change with the use of MOX fuel. The change in risk to the MEI of an LCF as a result of using MOX fuel during one of the design basis accidents evaluated is expected to range from a decrease of 10 percent to an increase of 3 percent. The change in risk to the MEI of a prompt fatality or LCF as a result of using MOX fuel during one of the beyond-design-basis accidents evaluated is expected to range from a 1 percent increase to a 22 percent increase. In the most severe accident evaluated, an ISLOCA, it is projected that the MEI would receive a fatal dose of radiation regardless of whether the reactor was using MOX fuel or LEU fuel at all of the proposed sites. It should be noted that the probability or estimated frequency of this accident occurring is very low; an average of 1 chance in 3.2 million per year of reactor operation.

Beyond-design-basis accidents, if they were to occur, would be expected to result in major impacts to the reactors and the surrounding communities and environment regardless of whether the reactor were using an LEU or partial MOX core. However, the probability of a beyond-design-basis accident actually happening is extremely unlikely, so the risk to an individual living within 80 km (50 mi) of the proposed reactors from these accidents is estimated to be low.

The following comments were received on the reactor analysis presented in the SPD Draft EIS and represent different or opposing views. Several comments indicated that the generic reactor analysis, presented in the *Storage and Disposition PEIS* and summarized in the SPD Draft EIS, was inadequate for a decision on the use of MOX fuel in specific reactors. Commentors, including the Blue Ridge Environmental Defense League, the Institute for Energy and Environmental Research, Serious Texans Against Nuclear Dumping, the Nuclear Control Institute, the Nuclear Information and Resource Service, and several individuals, while acknowledging that DOE committed to perform a site-specific reactor analysis in the SPD Final EIS, were concerned that such analysis should be available for public review prior to finalizing the document. Accordingly, the new analysis presented in this *Supplement* was performed using site-specific information and operating characteristics from the six reactors proposed for irradiation services and updated MOX fuel-loading estimates. NRC-accepted models were used to estimate impacts associated with normal operations, design basis, and beyond-design-basis accidents. The methodology used is consistent with DOE and industry practice, as well as the approach advocated by the commentors who requested additional analysis. The results are determined by the methodology and the assumptions. As indicated in this section, DOE's assumptions are based on its current planning, for example, 40 percent MOX cores rather than full cores as used in the *Storage and Disposition PEIS,* as well as site-specific meteorology and population data—all factors that influence the results.

4.28.2.5.1 Design Basis Accident Analysis

Design basis events are not expected to take place, but are postulated because their consequences would include the potential for the release of substantial amounts of radioactive material. They are the most drastic events that must be designed against and represent limiting design cases. The design basis accidents evaluated in this *Supplement* include a large-break loss-of-coolant accident (LOCA) and a fuel-handling accident.

The large-break LOCA is defined as a break equivalent in size to a double-ended rupture of the largest pipe of the reactor coolant system. Following this rupture of a reactor coolant pipe, the emergency core cooling system keeps cladding temperatures well below melting, ensuring that the core remains intact and in a coolable geometry. The increase in cladding temperature and rapid depressurization of the core, however, may cause some cladding failure in the hottest regions of the core. Thus, a fraction of the fission products accumulated in the pellet-cladding gap may be released to the reactor coolant system and thereby to the containment. Although no core melting would occur during this LOCA, a gross release of fission products is evaluated consistent with NRC methodology. For a gross release of fission products to occur, a number of simultaneous and extended failures in the engineered safety feature systems would be required.

The fuel-handling accident is defined as dropping of a spent fuel assembly resulting in breaching of the fuel rod cladding. This breach would release a portion of the volatile fission gases from the damaged fuel rods. Although this fuel-handling accident would realistically result in only a fraction of the fuel rods being damaged, all the fuel rods in the assembly are assumed to be damaged consistent with NRC methodology.

No major increase in estimated impacts would be expected from design basis accidents at the proposed reactor sites due to the use of MOX fuel. In fact, the risk from the postulated fuel-handling accident at all three sites would slightly decrease as a result of using MOX fuel. The fuel-handling accident doses are driven by the noble gases, primarily krypton. The percentage of the dose attributable to krypton is 58 percent at Catawba, 56 percent at McGuire, and 54 percent at North Anna. With the 40 percent MOX core, the MOX/LEU ratios for the krypton isotopes range from 0.78–0.89 indicating that there is less krypton present in a partial MOX core. The combination of the low MOX/LEU ratio and the large percentage of dose contribution associated with krypton results in a lower dose for this accident with a 40 percent MOX core.

The doses to the surrounding population within 80 km (50 mi) from a LOCA are expected to be about 3 percent higher for a partial MOX core versus a full LEU core. The LOCA doses are driven by radioactive isotopes of iodine. The percentage of dose attributable to iodine in a LOCA is approximately 97 percent at each reactor site. Because the iodine MOX/LEU ratios average slightly over one, indicating that there is more iodine present in a partial MOX core, the dose also rises slightly for this accident.

Catawba Design Basis Accident Analysis

Table 4.28–5 presents the results of this analysis for design basis accidents at Catawba. (To derive the increase or decrease in risk associated with the use of MOX fuel at any of the proposed reactors, subtract the risk associated with the full LEU core from the same risk for a partial MOX core for any of the accidents presented in Tables 4.28–5 through 4.28–7 and 4.28–10 through 4.28–12. For example, the risk to the MEI from a LOCA at Catawba, as shown in Table 4.28–5, is calculated by subtracting 8.64×10^{-8} from 8.88×10^{-8} for an increase in risk of 2.4×10^{-9}. All risks have been rounded to two significant figures, so, in cases where the difference is only one digit, the numbers have been extended to two significant figures using model results.)

The results indicate that the highest risk increase to the surrounding population for a design basis accident with a partial MOX core configuration instead of a full LEU core is 3.3 percent from the LOCA. The increased risk from the use of MOX fuel to the noninvolved worker[2] is one fatality every 210 million years (4.8×10^{-9} per 16-year campaign[3]); the MEI, one fatality every 420 million years (2.4×10^{-9} per 16-year campaign); and the general population, one fatality every 100,000 years (6.4×10^{-6} per 16-year campaign).

McGuire Design Basis Accident Analysis

Table 4.28–6 presents the results of this analysis for design basis accidents at McGuire.

The results indicate that the highest risk increase to the surrounding population for a design basis accident with a partial MOX core configuration instead of a full LEU core is approximately 3.0 percent from the LOCA. The increased risk from the use of MOX fuel to the noninvolved worker is one fatality every 69 million years (1.4×10^{-8} per 16-year campaign); the MEI, one fatality every 120 million years (8.0×10^{-9} per 16-year campaign); and the general population, one fatality every 78,000 years (1.3×10^{-5} per 16-year campaign).

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2 During a design-basis accident at a commercial reactor the involved workers are defined for the purposes of this *Supplement* as control room operators. Control rooms at commercial reactors are designed so that during a design basis accident, the doses to control room operators are mitigated by emergency systems. These systems include isolation dampers, emergency ventilation systems, bottled air supplies, and high-efficiency particulate air (HEPA) filtration to lower the doses to control room operators. Control room operator doses are predominantly from noble gases and iodine because the HEPA filtration removes almost all of the particulates. Therefore, the assumption is made that an unprotected noninvolved worker (i.e., all workers except those in the control room at the time of the accident) would most likely receive a larger dose. Because the objective of the analysis is to determine the maximum increased risk from a partial MOX core versus an LEU core, the noninvolved worker was chosen as the onsite receptor.

3 If MOX fuel is used in the proposed reactors, it is estimated that it will take approximately 16 years to irradiate all of the surplus plutonium currently considered for use in MOX fuel.

NORTH ANNA DESIGN BASIS ACCIDENT ANALYSIS

Table 4.28–7 presents the results of this analysis for design basis accidents at North Anna.

The results indicate that the highest risk increase to the surrounding population for a design basis accident with a partial MOX core configuration instead of a full LEU core is approximately 2.5 percent from the LOCA. The increased risk from the use of MOX fuel to the noninvolved worker is one fatality every 7.8 billion years (1.3×10^{-10} per 16-year campaign); the MEI, one fatality every 31 billion years (3.2×10^{-11} per 16-year campaign); and the general population, one fatality every 6.2 million years (1.6×10^{-7} per 16-year campaign).

Table 4.28–5. Design Basis Accident Impacts for Catawba With LEU and MOX Fuels

			Impacts on Noninvolved Worker			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	Frequency (per year)	LEU or MOX Core	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (person-rem)	Latent Cancer Fatalities[c]	Risk of Latent Cancer Fatalities (over campaign)[d]
Loss-of-coolant accident	7.50×10^{-6}	LEU	3.78	1.51×10^{-3}	1.81×10^{-7}	1.44	7.20×10^{-4}	8.64×10^{-8}	3.64×10^{3}	1.82	2.19×10^{-4}
		MOX	3.85	1.54×10^{-3}	1.86×10^{-7}	1.48	7.40×10^{-4}	8.88×10^{-8}	3.75×10^{3}	1.88	2.26×10^{-4}
Spent-fuel-handling accident[e]	1.00×10^{-4}	LEU	0.27	1.10×10^{-4}	1.78×10^{-7}	0.13	6.90×10^{-5}	1.10×10^{-7}	1.12×10^{2}	5.61×10^{-2}	8.98×10^{-5}
		MOX	0.26	1.05×10^{-4}	1.68×10^{-7}	0.13	6.55×10^{-5}	1.05×10^{-7}	1.10×10^{2}	5.48×10^{-2}	8.77×10^{-5}

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (762 m [2,500 ft])—given exposure to the indicated dose.

[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (762 m [2,500 ft]).

[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.

[d] Risk of cancer fatalities over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).

[e] Postulated design basis accidents at commercial reactors are considered extremely unlikely events. They are estimated to have a frequency of between 1.0×10^{-4} and 1.0×10^{-6} per year. Because a spent-fuel-handling accident does not have a calculated frequency associated with it, it has been estimated to have the highest frequency for the purposes of this analysis.

Key: LEU, low-enriched uranium.

Table 4.28–6. Design Basis Accident Impacts for McGuire With LEU and MOX Fuels

			Impacts on Noninvolved Worker			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	Frequency (per year)	LEU or MOX Core	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (person-rem)	Latent Cancer Fatalities[c]	Risk of Latent Cancer Fatalities (over campaign)[d]
Loss-of-coolant accident	1.50×10^{-5}	LEU	5.31	2.12×10^{-3}	5.10×10^{-7}	2.28	1.14×10^{-3}	2.74×10^{-7}	3.37×10^{3}	1.68	4.03×10^{-4}
		MOX	5.46	2.18×10^{-3}	5.25×10^{-7}	2.34	1.17×10^{-3}	2.82×10^{-7}	3.47×10^{3}	1.73	4.16×10^{-4}
Spent-fuel-handling accident[e]	1.00×10^{-4}	LEU	0.392	1.57×10^{-4}	2.51×10^{-7}	0.212	1.06×10^{-4}	1.70×10^{-7}	99.1	4.96×10^{-2}	7.94×10^{-5}
		MOX	0.373	1.49×10^{-4}	2.38×10^{-7}	0.201	1.01×10^{-4}	1.62×10^{-7}	97.3	4.87×10^{-2}	7.79×10^{-5}

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (762 m [2,500 ft])—given exposure to the indicated dose.

[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (762 m [2,500 ft]).

[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.

[d] Risk of cancer fatalities over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).

[e] Postulated design basis accidents at commercial reactors are considered extremely unlikely events. They are estimated to have a frequency of between 1.0×10^{-4} and 1.0×10^{-6} per year. Because a spent-fuel-handling accident does not have a calculated frequency associated with it, it has been estimated to have the highest frequency for the purposes of this analysis.

Key: LEU, low-enriched uranium.

Table 4.28–7. Design Basis Accident Impacts for North Anna With LEU and MOX Fuels

			Impacts on Noninvolved Worker			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	Frequency (per year)	LEU or MOX Core	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (person-rem)	Latent Cancer Fatalities[c]	Risk of Latent Cancer Fatalities (over campaign)[d]
Loss-of-coolant accident	2.10×10^{-5}	LEU	0.114	4.56×10^{-5}	1.53×10^{-8}	3.18×10^{-2}	1.59×10^{-5}	5.34×10^{-9}	39.4	1.97×10^{-2}	6.62×10^{-6}
		MOX	0.115	4.60×10^{-5}	1.55×10^{-8}	3.20×10^{-2}	1.60×10^{-5}	5.38×10^{-9}	40.3	2.02×10^{-2}	6.78×10^{-6}
Spent-fuel-handling accident[e]	1.00×10^{-4}	LEU	0.261	1.04×10^{-4}	1.66×10^{-7}	9.54×10^{-2}	4.77×10^{-5}	7.63×10^{-8}	29.4	1.47×10^{-2}	2.35×10^{-5}
		MOX	0.239	9.56×10^{-5}	1.53×10^{-7}	8.61×10^{-2}	4.31×10^{-5}	6.90×10^{-8}	27.5	1.38×10^{-2}	2.21×10^{-5}

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (1,349 m [4,426 ft])—given exposure to the indicated dose.

[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—a noninvolved worker at a distance of 640 m (2,100 ft) or the maximally exposed offsite individual at the site boundary (1,349 m [4,426 ft]).

[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.

[d] Risk of cancer fatalities over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).

[e] Postulated design basis accidents at commercial reactors are considered extremely unlikely events. They are estimated to have a frequency of between 1.0×10^{-4} and 1.0×10^{-6} per year. Because a spent-fuel-handling accident does not have a calculated frequency associated with it, it has been estimated to have the highest frequency for the purposes of this analysis.

Key: LEU, low-enriched uranium.

4.28.2.5.2 Beyond-Design-Basis Accident Analysis

Only beyond-design-basis accident scenarios that lead to containment bypass or failure were evaluated because these are the accidents with the greatest potential consequences. The public health and environmental consequences would be significantly less for accident scenarios that do not lead to containment bypass or failure. A steam generator tube rupture, early containment failure, late containment failure, and an ISLOCA were chosen as the representative set of beyond-design-basis accidents.

Commercial reactors, licensed by NRC, are required to complete Individual Plant Examinations (IPEs) to assess plant vulnerabilities to severe accidents. An acceptable method of completing the IPEs is to perform a PRA. A PRA evaluates, in full detail (quantitatively), the consequences of all potential events caused by the operating disturbances (known as internal initiating events) within each plant. The PRA uses realistic criteria and assumptions in evaluating the accident progression and the systems required to mitigate each accident. The PRAs for the proposed reactors provided the required data to evaluate beyond-design-basis accidents.

A beyond-design-basis steam generator tube rupture induced by high temperatures represents a containment bypass event. Analyses have indicated a potential for very high gas temperatures in the reactor coolant system during accidents involving core damage with the primary system at high pressure. The high temperature could fail the steam generator tubes long before the core begins to relocate. As a result of the tube rupture, the secondary (nonradioactive) side may be exposed to high pressure. This pressure would likely cause relief valves to open. If these valves failed to reclose, an open pathway from the vessel to the environment would result.

An early containment failure is defined as the failure of containment prior to or very soon (within a few hours) after breach of the reactor vessel. A variety of mechanisms can cause failure such as direct contact of core debris with the containment, rapid pressure and temperature loads, hydrogen combustion, and fuel-coolant interactions. Early containment failure can be important because it tends to result in shorter warning times for initiating public protective measures and because radionuclide releases would generally be more severe than if the containment were to fail late.

A late containment failure involves failure of the containment several hours after breach of the reactor vessel. A variety of mechanisms can cause late containment failure such as gradual pressure and temperature increase, hydrogen combustion, and basemat melt-through by core debris.

An ISLOCA refers to a class of accidents in which the reactor coolant system pressure boundary interfacing with a supporting system of lower design pressure is breached. If this occurs, the low-pressure system would be overpressurized and could rupture outside the containment. This failure would establish a flow path directly to the environment or, sometimes, to another building of small-pressure capacity.

Each of these accidents has a warning time and a release time associated with it. The warning time is the time at which notification is given to offsite emergency response officials to initiate protective measures for the surrounding population. The release time is when the release to the environment begins. The minimum time between the warning time and the release time is one-half hour; enough time to evacuate onsite personnel. This also conservatively assumes that an onsite emergency has not been declared prior to initiating an offsite notification. Intact containment severe accident scenarios, which were not analyzed because of their insubstantial offsite consequences, take place on an even longer timeframe.

For severe accident scenarios that postulate large abrupt releases, there exists a possibility for prompt fatalities. Prompt fatalities may occur if the radiation dose is sufficiently high. Table 4.28–8 shows the number of prompt fatalities in the offsite population estimated from a postulated beyond-design-basis steam generator tube rupture and ISLOCA. None of the other accidents evaluated in the SPD EIS is expected to result in prompt fatalities.

Table 4.28–8. Estimated Prompt Fatalities in the Public From Beyond-Design-Basis Reactor Accidents

Reactor	LEU Core	Partial MOX Core
Steam generator tube rupture		
Catawba	1	1
McGuire	1	1
North Anna	0	0
Interfacing systems loss-of-coolant accident		
Catawba	815	843
McGuire	398	421
North Anna	54	60

Table 4.28–9 shows the difference in accident consequences for reactors using MOX fuel versus LEU fuel. For beyond-design-basis accidents, the consequences would be expected to be higher, with the largest increase associated with an ISLOCA. This is because the MOX fuel would release a higher actinide inventory in a severe accident. The increased impacts of an ISLOCA range from 10 to 15 percent and are estimated, on average, to be about 13 percent greater to the general population living within 80 km (50 mi) of the reactor with a partial MOX core instead of an LEU core. It should be noted that this accident has a very low estimated frequency of occurrence, an average of 1 chance in 3.2 million per year of reactor operation for the reactors being proposed to irradiate MOX fuel.

Table 4.28–9. Ratio of Accident Impacts for MOX-Fueled and Uranium-Fueled Reactors (MOX Impacts/LEU Impacts)

	Catawba		McGuire		North Anna		S&D PEIS	
Accident	MEI	Population	MEI	Population	MEI	Population	MEI	Population
Design basis accidents								
LOCA[a]	1.03	1.03	1.03	1.03	1.01	1.03	NA	NA
Fuel-handling accident[a]	0.95	0.98	0.95	0.98	0.90	0.94	NA	NA
Beyond-design-basis accidents								
SG tube rupture	1.06	1.04	1.06	1.04	1.16	1.07	0.94	0.94
Early containment failure	1.01	1.05	1.03	1.02	1.10	1.01	0.96	0.97
Late containment failure	1.07	0.96	1.01	0.97	1.03	1.09	1.07	1.08
ISLOCA	1.14	1.12	1.12	1.10	1.22	1.15	0.92	0.93

[a] No design basis accidents were analyzed in the *Storage and Disposition PEIS.*

Key: ISLOCA, interfacing systems loss-of-coolant accident; LEU, low-enriched uranium; LOCA, loss-of-coolant accident; MEI, maximally exposed individual; NA, not applicable; S&D PEIS, *Storage and Disposition of Weapons-Usable Fissile Material Final Programmatic Environmental Impact Statement*; SG, steam generator.

CATAWBA BEYOND-DESIGN-BASIS ACCIDENTS

Table 4.28–10 shows the risks of LCFs associated with all of the evaluated Catawba beyond-design-basis accidents.

Table 4.28–10. Beyond-Design-Basis Accident Impacts for Catawba With LEU and MOX Fuels

			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	**Frequency (per year)**	**LEU or MOX Core**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (person-rem)**	**Latent Cancer Fatalities[c]**	**Risk of Latent Cancer Fatalities (over campaign)[d]**
SG tube rupture[e]	6.31×10^{-10}	LEU	3.46×10^{2}	0.346	3.49×10^{-9}	5.71×10^{6}	2.86×10^{3}	2.88×10^{-5}
		MOX	3.67×10^{2}	0.367	3.71×10^{-9}	5.93×10^{6}	2.96×10^{3}	2.99×10^{-5}
Early containment failure	3.42×10^{-8}	LEU	5.97	2.99×10^{-3}	1.63×10^{-9}	7.70×10^{5}	3.85×10^{2}	2.11×10^{-5}
		MOX	6.01	3.01×10^{-3}	1.65×10^{-9}	8.07×10^{5}	4.04×10^{2}	2.21×10^{-4}
Late containment failure	1.21×10^{-5}	LEU	3.25	1.63×10^{-3}	3.15×10^{-7}	3.93×10^{5}	1.96×10^{2}	3.79×10^{-2}
		MOX	3.48	1.74×10^{-3}	3.38×10^{-7}	3.78×10^{5}	1.89×10^{2}	3.66×10^{-2}
ISLOCA	6.90×10^{-8}	LEU	1.40×10^{4}	1	1.10×10^{-6}	2.64×10^{7}	1.32×10^{4}	1.46×10^{-2}
		MOX	1.60×10^{4}	1	1.10×10^{-6}	2.96×10^{7}	1.48×10^{4}	1.63×10^{-2}

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—the maximally exposed offsite individual at the site boundary (762 m [2,500 ft])—given exposure to the indicated dose.
[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—the maximally exposed offsite individual at the site boundary (762 m [2,500 ft]).
[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.
[d] Risk of cancer fatalities over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).
[e] McGuire timing and release fractions were used to compare like scenarios.
Key: ISLOCA, interfacing systems loss-of-coolant accident; LEU, low-enriched uranium; SG, steam generator.

At Catawba, the greatest increase in risk of LCFs from the use of a partial MOX core to the surrounding population within 80 km (50 mi) for a beyond-design-basis accident is from an ISLOCA. If this accident were to occur, the consequences, in terms of LCFs and prompt fatalities in the general population within 80 km (50 mi), would be approximately 12 percent greater than those from an ISLOCA with an LEU core. It would be expected to result in approximately 14,000 fatalities with an LEU core and 15,600 fatalities with a partial MOX core. The increased risk in terms of an LCF in the surrounding population associated with the use of MOX fuel would be one additional LCF every 570 years or 1.7×10^{-3} per 16-year campaign. The increased risk in terms of a prompt fatality is one additional fatality every 32,000 years or 3.1×10^{-5} per 16-year campaign. No increase in risk to the MEI would be expected due to the severity of this accident. The MEI would be expected to receive a fatal dose regardless of whether the core was partially fueled with MOX fuel or not, so the risk of a fatality is estimated to be the same in either case; 1 in 900,000 years or 1.1×10^{-6} per 16-year campaign.

At Catawba, the highest risk from a beyond-design-basis accident to the surrounding population within 80 km (50 mi) is from a late containment failure regardless of core type. If this accident were to occur with a partial MOX core, the consequences, in terms of LCFs, would be approximately 3.6 percent lower than those from the same accident with an LEU core. This accident would be expected to result in 196 LCFs with an LEU core and 189 LCFs with a partial MOX core. The decreased risk to the population associated with the use of MOX fuel would be one less LCF every 780 years or 1.3×10^{-3} per 16-year campaign. No prompt fatalities would be expected to result from this accident. However, the risk to the MEI would be expected to increase by approximately 6.7 percent if a partial MOX core were being used.[4] The increased risk of an LCF to the MEI from this accident with a partial MOX core is estimated to be one in 45 million years or 2.2×10^{-8} per 16-year campaign.

McGuire Beyond-Design-Basis Accidents

Table 4.28–11 shows the risks of LCFs associated with all of the evaluated McGuire beyond-design-basis accidents.

Table 4.28–11. Beyond-Design-Basis Accident Impacts for McGuire With LEU and MOX Fuels

			Impacts at Site Boundary			Impacts on Population Within 80 km		
Accident	**Frequency (per year)**	**LEU or MOX Core**	**Dose (rem)**	**Probability of Latent Cancer Fatality[a]**	**Risk of Latent Cancer Fatality (over campaign)[b]**	**Dose (person-rem)**	**Latent Cancer Fatalities[c]**	**Risk of Latent Cancer Fatalities (over campaign)[d]**
SG tube rupture[e]	5.81×10^{-9}	LEU	6.10×10^{2}	0.610	5.66×10^{-8}	5.08×10^{6}	2.54×10^{3}	$2.37\times10_{-4}$
		MOX	6.47×10^{2}	0.647	6.02×10^{-8}	5.28×10^{6}	2.64×10^{3}	2.45×10^{-4}
Early containment failure	9.89×10^{-8}	LEU	12.2	6.10×10^{-3}	9.65×10^{-9}	7.90×10^{5}	3.95×10^{2}	6.26×10^{-4}
		MOX	12.6	6.30×10^{-3}	9.97×10^{-9}	8.04×10^{5}	4.02×10^{2}	6.37×10^{-4}
Late containment failure	7.21×10^{-6}	LEU	2.18	1.09×10^{-3}	1.26×10^{-7}	3.04×10^{5}	1.52×10^{2}	1.76×10^{-2}
		MOX	2.21	1.11×10^{-3}	1.28×10^{-7}	2.96×10^{5}	1.48×10^{2}	1.71×10^{-2}
ISLOCA	6.35×10^{-7}	LEU	1.95×10^{4}	1	1.02×10^{-5}	1.79×10^{7}	8.93×10^{3}	0.091
		MOX	2.19×10^{4}	1	1.02×10^{-5}	1.97×10^{7}	9.85×10^{3}	0.10

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—the maximally exposed offsite individual at the site boundary (762 m [2,500 ft])—given exposure to the indicated dose.
[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—the maximally exposed offsite individual at the site boundary (762 m [2,500 ft]).
[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.
[d] Risk of cancer fatalities over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).
[e] McGuire timing and release fractions were used to compare like scenarios.
Key: ISLOCA, interfacing systems loss-of-coolant accident; LEU, low-enriched uranium; SG, steam generator.

At McGuire, the greatest increase in risk from the use of a partial MOX core and the highest risk regardless of core type to the surrounding population within 80 km (50 mi) for a beyond-design-basis accident is from an ISLOCA. If this accident were to occur, the consequences, in terms of LCFs and prompt fatalities, in the general population within 80 km (50 mi) would be approximately 10 percent greater than those from an ISLOCA with an LEU core. It would be expected to result in approximately 9,300 fatalities with an LEU core

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[4] For the late containment failure scenario at Catawba and McGuire, the MEI dose increases while the population dose decreases. The MEI dose increases because 96 percent of the MEI dose is from direct exposure during the initial plume passage. With a 40 percent MOX core, there is approximately double the actinide inventory. Because the actinide isotopes contribute greatly to the inhalation dose, the MEI dose increases. The majority of the population dose (78 percent) is from long-term effects, primarily groundshine. With a 40 percent MOX core, the majority of the fission products decrease, resulting in a lower groundshine dose. Therefore, the population dose decreases.

and 10,300 fatalities with a partial MOX core. The increased risk, in terms of an LCF, in the surrounding population would be one additional LCF every 110 years or 9.3×10^{-3} per 16-year campaign. The increased risk in terms of a prompt fatality would be one additional fatality every 4,300 years or 2.3×10^{-4} per 16-year campaign. For the same reasons as discussed above for Catawba, no increase in risk to the MEI would be expected due to the severity of this accident. The risk to the MEI of a fatality is estimated to be the same in either case, one fatality every 98,000 years or 1.0×10^{-5} per 16-year campaign.

North Anna Beyond-Design-Basis Accidents

Table 4.28–12 shows the risks of LCFs associated with all of the evaluated North Anna beyond-design-basis accidents.

Table 4.28–12. Beyond-Design-Basis Accident Impacts for North Anna With LEU and MOX Fuels

			Impacts on Site Boundary			Impacts on Population Within 80 km		
Accident	Frequency (per year)	LEU or MOX Core	Dose (rem)	Probability of Latent Cancer Fatality[a]	Risk of Latent Cancer Fatality (over campaign)[b]	Dose (person-rem)	Latent Cancer Fatalities[c]	Risk of Latent Cancer Fatalities (over campaign)[d]
SG tube rupture[e]	7.38×10^{-6}	LEU	2.09×10^{2}	0.209	2.46×10^{-5}	1.73×10^{6}	8.63×10^{2}	0.102
		MOX	2.43×10^{2}	0.243	2.86×10^{-5}	1.84×10^{6}	9.20×10^{2}	0.109
Early containment failure[e]	1.60×10^{-7}	LEU	19.6	1.96×10^{-2}	5.02×10^{-8}	8.33×10^{5}	4.17×10^{2}	1.07×10^{-3}
		MOX	21.6	2.16×10^{-2}	5.54×10^{-8}	8.42×10^{5}	4.21×10^{2}	1.08×10^{-3}
Late containment failure[e]	2.46×10^{-6}	LEU	1.12	5.60×10^{-4}	2.21×10^{-8}	4.04×10^{4}	20.2	7.95×10^{-4}
		MOX	1.15	5.75×10^{-4}	2.26×10^{-8}	4.43×10^{4}	22.1	8.70×10^{-4}
ISLOCA[e]	2.40×10^{-7}	LEU	1.00×10^{4}	1	3.84×10^{-6}	4.68×10^{6}	2.34×10^{3}	8.99×10^{-3}
		MOX	1.22×10^{4}	1	3.84×10^{-6}	5.41×10^{6}	2.70×10^{3}	1.04×10^{-2}

[a] Likelihood (or probability) of cancer fatality to a hypothetical individual—the maximally exposed offsite individual at the site boundary (1,349 m [4,426 ft])—given exposure to the indicated dose.
[b] Risk of cancer fatality over the estimated 16-year campaign to a hypothetical individual—the maximally exposed offsite individual at the site boundary (1,349 m [4,426 ft]).
[c] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km (50 mi) given exposure to the indicated dose.
[d] Risk of cancer fatalities over the estimated 16-year campaign in the entire offsite population out to a distance of 80 km (50 mi).
[e] McGuire release durations and warning times were used in lieu of site specific data.
Key: ISLOCA, interfacing systems loss-of-coolant accident; LEU, low-enriched uranium; SG, steam generator.

At North Anna, the greatest increase in risk from the use of a partial MOX core to the surrounding population within 80 km (50 mi) for a beyond-design-basis accident is from an ISLOCA. If this accident were to occur, the consequences, in terms of LCFs and prompt fatalities in the general population within 80 km (50 mi) would be approximately 15 percent greater than those from an ISLOCA with an LEU core. It would be expected to result in approximately 2,400 fatalities with an LEU core and 2,800 fatalities with a partial MOX core. The increased risk, in terms of an LCF, to the surrounding population, would be one additional fatality every 730 years or 1.4×10^{-3} per 16-year campaign. The increased risk in terms of a prompt fatality is one additional fatality every 43,000 years or 2.3×10^{-5} per 16-year campaign. For the same reasons as discussed above for Catawba, no increase in risk to the MEI would be expected due to the severity of this accident. The risk to the

MEI of a fatality is estimated to be the same in either case, one fatality every 260,000 years or 3.8×10^{-6} per 16-year campaign.

At North Anna, the highest risk from a beyond-design-basis accident to the surrounding population within 80 km (50 mi) is from a steam generator tube rupture regardless of core type. If this accident were to occur with a partial MOX core, the consequences, in terms of LCFs, would be approximately 6.6 percent greater than those from the same accident with an LEU core. It would be expected to result in approximately 860 LCFs with an LEU core and 920 LCFs with a partial MOX core. The increased risk, in terms of an LCF, to the surrounding population would be one additional LCF every 150 years or 6.7×10^{-3} per 16-year campaign. No prompt fatalities would be expected to result from this accident. The risk to the MEI would be expected to increase by approximately 16 percent if a partial MOX core were being used. The increased risk to the MEI of a fatal dose from this accident with a partial MOX core is estimated to be 1 in 250,000 years or 4.0×10^{-6} per 16-year campaign.

4.28.2.6 Transportation

Transportation required under the MOX approach would include shipments of MOX fuel from the proposed MOX facility to the proposed reactor sites for irradiation. It is estimated that approximately 830 shipments of fresh MOX fuel would be shipped to the proposed reactor sites in DOE-provided SSTs. While these shipments would likely replace similar shipments of fresh LEU fuel to the reactor sites, thereby reducing the transportation risks associated with this fuel, this *Supplement* analyzes the shipments on a stand-alone basis to estimate the maximum risk to the public. (The shipment of spent fuel is being considered in DOE's EIS for a potential geologic repository that includes in its inventory the MOX fuel that would be generated from the surplus plutonium disposition program.)

The highest dose for these transportation activities would be associated with those alternatives that include locating the MOX facility at Hanford because it is the candidate site farthest from the proposed reactor sites. Similarly, the lowest dose would be associated with alternatives considering placing the MOX facility at SRS because this is the candidate site closest to the proposed reactors.

The estimated dose to the transportation crew from the incident-free transportation activities of fresh MOX fuel to the proposed reactors is estimated to range from 0.036 rem to 0.19 rem depending on the location of the MOX facility. In terms of the number of LCFs in the crew from this transportation, the number would range from 1.4×10^{-5} to 7.8×10^{-5}. The estimated dose to the public from the incident-free transportation of this material is estimated to range from 0.019 rem to 0.092 rem. In terms of the number of LCFs in the public from this transportation, the number would range from 9.3×10^{-6} to 4.6×10^{-5}. The estimated number of LCFs from emissions associated with this transportation would range from 9.0×10^{-4} to 1.4×10^{-2}. Thus, no fatalities would be expected as a result of incident-free transportation of this material.

The number of LCFs expected from transportation accidents is also projected to be small. The estimated dose from accidents involving this MOX fuel is projected to range from 0.15 rem to 0.46 rem. These doses range from 7.5×10^{-5} to 2.3×10^{-4} LCFs in the public. In terms of a traffic fatality from accidents, it is estimated that this transportation would result in between 5.6×10^{-3} and 3.0×10^{-2} traffic fatalities. Thus, no fatalities would be expected as a result of accidents associated with this transportation.

4.28.2.7 Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs Federal agencies to identify and address, as appropriate, disproportionately high and adverse health or environmental effects of their programs, policies, and activities on minority and low-income populations. The Council on Environmental Quality has oversight responsibility for documentation prepared in compliance with the National Environmental Policy Act (NEPA). In December 1997, the Council released guidance on environmental justice under NEPA (CEQ 1997). The Council's guidance was adopted as the basis for the analysis of environmental justice contained in the SPD EIS. This section provides an assessment of the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations that could result from implementation of the alternatives for the proposed action.

As demonstrated throughout the analyses presented in Section 4.28, normal irradiation of MOX fuel in existing, commercial reactors would pose no significant health risks to the public. As shown in Section 4.28.2.4, the expected number of LCFs would not increase as a result of radiation released during normal operations for the irradiation of this fuel because there would be essentially no increase in radiation received by the general population from the use of MOX fuel.

Some of the reactor accidents would be expected to result in LCFs and prompt fatalities among the general public regardless of whether the reactor was fueled with MOX fuel or LEU fuel. However, it is unlikely that any of these accidents would occur. The consequences associated with use of MOX fuel would range from 7 less fatalities expected from a late containment failure at Catawba to 1,628 additional fatalities from an ISLOCA at Catawba. However, because these accidents have a very small frequency, the risk to the general population only changes by a small amount. The greatest increase in risk to the general population of an LCF from a severe reactor accident using MOX fuel is an increase of 9.3×10^{-3} over the 16-year MOX campaign; the equivalent of one additional fatality every 110 years. The increased risk of a prompt fatality from this accident due to the use of MOX fuel would be 2.3×10^{-4} over the 16-year MOX campaign; the equivalent of one additional fatality every 4,300 years. Thus, the use of MOX fuel in the proposed reactors would pose no significant risks to the general population residing within the area potentially affected by radiological contamination.

As shown in Section 4.28.2.6, no radiological or nonradiological fatalities would be expected to result from the incident-free transportation of MOX fuel to the proposed reactors. Nor would radiological or nonradiological fatalities be expected to result from transportation accidents.

The implementation of the MOX fuel irradiation program at any of the proposed reactor sites would pose no significant risks to the public, nor would implementation of this program pose significant risks to groups within the general public, including the risk of disproportionately high and adverse effects on minority and low-income populations. The population surrounding the North Anna site is projected to have a larger minority population then the national average by 2015 (35.8 percent versus 34 percent) (See Appendix M). However, the increased risk associated with the use of MOX fuel at this site is low. The greatest increase in risk of LCFs is 1.4×10^{-3} over the 16-year MOX campaign for an ISLOCA accident. If this accident were to occur, the increased number of fatalities due to the use of MOX fuel in the general population within 80 km (50 mi) of the North Anna site would be 366, of which 131 would be expected to be from minority populations; approximately 7 fatalities would be considered to be disproportionate versus the national average.

4.28.2.8 Spent Fuel

As shown in Table 4.28–13, it is likely that some additional spent LEU fuel would be generated by using a partial MOX core in the mission reactors. The amount of additional spent nuclear fuel generated is estimated to range from approximately 2 to 16 percent of the total amount of spent fuel that would be generated by the proposed reactors during the time period MOX fuel would be used. The reactor sites intend to manage the spent MOX fuel the same as spent LEU fuel, by storing it in the reactor's spent fuel pool or placing it in dry storage. The amount of additional spent fuel is not expected to impact spent fuel management at the reactor sites.

Table 4.28–13. Total Additional Spent Fuel Assemblies Generated by MOX Fuel Irradiation

Reactor	Number of Spent Fuel Assemblies Generated With No MOX Fuel	Number of Additional Spent Fuel Assemblies With MOX Fuel	Percent Increase
Catawba 1	672	12	1.8
Catawba 2	672	12	1.8
McGuire 1	756	12	1.6
McGuire 2	672	12	1.8
North Anna 1	420	67	16.0
North Anna 2	540	84	15.6
Total	3,732	199	5.3

For the four units at Catawba and McGuire, all of the additional spent nuclear fuel assemblies would be generated during the transition cycles from LEU to MOX fuel. Additional assemblies help to maintain peaking below design and regulatory limits, and compensate for the greater end-of-cycle reactivity. For Catawba and McGuire, once equilibrium is reached in the partial MOX core, additional fuel assemblies would not be required.

Like McGuire and Catawba, the North Anna units are expected to require additional LEU assemblies during the first transition cores. However, additional assemblies will also be required during equilibrium cycles because of operational considerations of the smaller North Anna cores (157 fuel assemblies compared to 193 each for the McGuire and Catawba units).

As core designs are finalized and optimized for MOX fuel, it may be possible to reduce MOX fuel assembly peaking and thereby reduce the number of additional assemblies required (and spent fuel generated) at the proposed reactors. As it currently stands, the North Anna site could generate approximately 16 percent more spent fuel by using MOX fuel than if the plants continued to use LEU fuel. The total amount of additional spent fuel generated by all six proposed reactors is estimated to be approximately 92 t (101 tons) of heavy metal. However, such MOX fuel is included in the inventory for the potential Nuclear Waste Policy Act geologic repository being studied by DOE. As discussed earlier, DOE is in the process of completing an EIS for a potential geologic repository.

4.28.2.9 Geology and Soils

No ground-disturbing activities related exclusively to the use of MOX fuel are proposed at any of the reactor sites. Therefore, there would be no impact on the reactor site's geology or soils resulting from the use of MOX fuel.

4.28.2.10 Water Resources

There would be no change in water usage or discharge of nonradiological pollutants resulting from use of MOX fuel in the proposed reactors. Each of the reactor sites discharges nonradiological wastewater in accordance with a National Pollutant Discharge Elimination System permit, or an analogous State-issued permit. Permitted outfalls discharge conventional and priority pollutants from the reactor and ancillary processes that are similar to discharges from most reactor sites. Monitoring, analyses, and toxicity testing are also consistent with the types of discharges. Discharge Monitoring Reports for North Anna (May 1994 through April 1998) and Catawba (calendar years 1995 through 1997) showed that, for the most part, there were only occasional noncompliances with permit limitations, only one of which occurred at an outfall receiving reactor process discharges. The effluent from outfall 001 at Catawba failed a quarterly chronic toxicity test in March 1996. However, a followup sample collected after receiving these results passed the test. During the period reviewed, Catawba experienced four noncompliances, two in 1995 and two in early 1996. North Anna exceeded the chlorine limitation at its sewage treatment facility, but this would neither affect, nor be affected by, the use of MOX fuel.

4.28.2.11 Ecological Resources

The use of MOX fuel in existing reactors would not be expected to result in any impacts on ecological resources at the proposed sites. There would be no new construction, and emissions of effluents from the reactors would not change significantly.

4.28.2.12 Cultural and Paleontological Resources

No ground-disturbing activities are proposed at the sites related exclusively to the use of MOX fuel. Therefore, the use of MOX fuel in existing reactors is not expected to affect cultural and paleontological resources at the proposed sites. Similarly, no impacts on Native American resources in the areas surrounding the reactor sites are expected.

4.28.2.13 Land Use

The proposed reactor sites would not require any additional land to support the use of MOX fuel in their reactors. This statement is consistent with information presented in the *Storage and Disposition PEIS* (DOE 1996b:4-720). Nor would the use of MOX fuel in an existing reactor affect the use of other onsite lands (e.g., buffer zones and undeveloped land areas would not be impacted). Prime farmland would not be affected and, because the use of MOX fuel would not result in an in-migration of workers, as discussed in Section 4.28.2.3, no indirect impacts on offsite lands would be expected.

4.28.2.14 Infrastructure

Existing site infrastructure would continue to serve the sites proposed to irradiate MOX fuel. Each site is equipped with water and an existing power distribution system that would adequately support the demands of the reactors should MOX fuel be used. Therefore, the proposed reactor sites would not require any additional infrastructure to support the use of MOX fuel in the reactors. This is consistent with information presented in the *Storage and Disposition PEIS* (DOE 1996b:4-721).

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